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LIGHTING AND MARKING FARM EQUIPMENT

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Introduction

Agriculture is one of the most hazardous occupations in the United States as determined by death rates. Excluding persons under 14 years of age, the National Safety Council (1993) estimates there were 37 deaths per 100,000 agricultural workers in 1992. Farm machinery and motor vehicles being used for farm related purposes are often involved in accidental agricultural deaths. The classes of injury causing agent with the greatest frequency of accidental occupational farm fatalities during 1992 in Iowa were tractors, machinery, and motor vehicles (IDPH, 1993). Together these three classes accounted for 64 percent of 83 recorded fatalities. Thirty-one percent of the agricultural injuries involving tractors, machinery or motor vehicles occurred during October and November (IDPH, 1993).

Nationally, 53 percent of tractor fatalities during 1992 involved overturns (National Safety Council, 1993). Although accidents with tractors and other farm machinery occurred more frequently in the farm yard or fields, public right-of-way was the third most frequent environment for Iowa tractor-related injuries during 1992 (IDPH, 1993). Fifteen percent of all tractor-related injuries occurred on a public roadway. During 1992 fifty-nine percent of Iowa agricultural work related injuries caused by motor vehicles involved in farm work occurred on public right-of-way. Lehtola et al. (1994) investigated 131 Iowa tractor-related accidents involving fatalities that occurred from 1988 through 1992. Eleven percent of accidents were on public roadways and involved other vehicles. Fourteen percent of 136 deaths were in this type of accident. Motor vehicle occupants were 12 of the 19 fatalities in this category. Twenty-one percent of accidents were tractor overturns that did not involve other vehicles.

The National Safety Council (1993) estimated 8,000 motor vehicle accidents during 1992 involving farm tractors or equipment. An estimated 100 of these were fatal. Although farm tractors and equipment were involved in less than 0.05% of all motor vehicle accidents, nationally, the percentage of all fatal motor vehicle accidents in which farm vehicles were involved was almost five times greater than the percentage of all accidents in which farm vehicles were involved. Mortimer (1983) concluded from analyzing similar data that exposure for the general public is limited because total numbers are low, but personal injury risks may be substantial. Earlier, Burke (1968) reported 280 fatalities in 25,000 accidents nationwide involving farm vehicles on public roads during 1967. Almost half of these accidents involved collisions with non-farm vehicles. The definition of farm vehicle is often decided by an investigating officer and limits the specific interpretation of such statistics for tractors and self-propelled agricultural machinery.

The Iowa Department of Transportation (Emery, 1993) recorded 305 motor vehicle accidents during 1992 involving farm vehicles and equipment, representing just 0.4% of all motor vehicle accidents, but 0.6% of all personal injury accidents and 2.3% of all fatal accidents. Forty-eight percent of Iowa accidents involving farm vehicles and equipment occurred from October through December. Rear-end collisions were the type most frequently reported for personal injury and fatality accidents.

The most frequent fatal accident situation for Iowa tractor accidents involving other vehicles on public roadways from 1988 through 1992 (Lehtola et al., 1994) was rear-end collision (43%). Other frequent accident situations were motorists attempting to pass tractors turning left (29%) and head-on collisions (29%). Lehtola et al. (1994) reported that some motorists striking the farm vehicle from the rear never braked and noted the importance of adequate lighting and marking. Haddon (1979) reported a reduction in rear-end collisions for New York taxi drivers when a brake light was placed in the middle of the rear windshield thus providing motorists better information on which to react.

Hill et al. (1992) surveyed the status of twenty-nine tractor safety components on 136 New York dairy farms. Defective or absent components found were combined into a safety score. A correlation between tractor age and safety score was reported. A greater prevalence of safety defects was observed with increasing tractor age.

Data are not available to directly estimate the number of harvest time accidents on public right-of-way involving grain transport. Iowa data do indicate that tractors, farm machinery and motor vehicles are often involved in fatal agricultural work related accidents and that a greater than random percentage occur during fall harvest. When farm equipment is involved in a motor vehicle accident, the chance of a fatality is increased. Iowa data indicate that almost half of public right-of-way accidents involving farm vehicles occur during the fall harvest period of October through December.

Public right-of-way accidents involving farm vehicles occur during both day and night (Emery, 1993). Observing that shortening daylengths and the change from daylight to standard time during harvest may contribute to accidents, however, can encourage equipment operators to use proper lighting and marking. Sunrise and sunset times (Naval Almanac Office, 1993) during harvest for two Iowa locations near the eastern and western borders of the state are

shown in table 1. After changing to standard time, grain wagons unloaded near 5:00 pm at commercial Iowa elevators must often travel public right-of-way after sunset.

The presence of safety equipment (including proper lighting, marking, rollover protection and hitch safety equipment) on tractors and wagons is important because of documented risks of operating farm vehicles on public rights-of-way during fall harvest.

Table 1. Clock sunrise and sunset times at two Iowa locations during fall harvest

	Davenport (41°27'N 90°35'W)		Council Bluffs (41°16'N 95°52'W)	
Date	Sunrise	Sunset	Sunrise	Sunset
	---------- h ----------			
October 1†	6:59 am	6:45 pm	7:20 am	7:06 am
October 15†	7:15 am	6:22 pm	7:35 am	6:43 am
November 1‡	6:34 am	4:57 pm	6:54 am	5:19 am
November 15‡	6:50 am	4:43 pm	7:11 am	5:05 am
December 1‡	7:09 am	4:34 pm	7:29 am	4:55 am

† Central daylight time in effect
‡ Central standard time in effect

Risks include interaction with other vehicles and overturns.

State requirements and ASAE standards

Lighting and marking requirements vary by state. Iowa code (Legislative Services Bureau, 1992) requires tractors and tractor-towed implement combinations traveling less than 40 km/h (25 mi/h) on public right-of-way to display an American Society of Agricultural Engineers (ASAE) approved slow moving vehicle emblem (SMV) visible from the rear. At any time from sunset to sunrise tractors and tractor-towed implement combinations must display a minimum of one white light visible 500 ft from the front, and one red light and one amber flashing light visible 500 ft from the rear. Iowa code does not specify hitch requirements for implements of agricultural husbandry.

ASAE standards for lighting and marking of agricultural field equipment on public right-of-ways are stricter than the current Iowa code requirements:

- Two white headlamps, the same height and laterally centered about the tractor centerline that are visible from the front.
- One red tail lamp positioned less than 5 ft left of the vehicle centerline that is visible from the rear.
- Two amber flashing warning lamps symmetrically mounted that are visible both from the front and rear.
- Two red reflectors marking left and right projections (tail lamp lens acceptable) that are visible to the rear.

If the towed wagon extends more than 4 ft left of the hitch an amber reflector marking the front left projection is to be visible to oncoming traffic. Towed wagons extending more than 33 ft behind the hitch are to have amber reflectors visible from the side and spaced at maximum intervals of 16 ft.

ASAE standards for agricultural equipment towed on highways require a retainer on the hitch pin and a safety chain attached by a hook latch with an ASAE tag specifying the towed load gross weight.

To determine if lighting, marking, hitch, and rollover safety equipment is being used on harvest transport equipment, a survey was conducted during fall 1992.

Survey Procedures

Data collection was accomplished as part of an educational project using teams of vocational agriculture students (FFA) to conduct checks at local commercial grain elevators. This method to collect data also increased safety awareness during harvest among a greater number of Iowa equipment operators. Although the tractors and wagons surveyed were a random sample of those unloading grain at specific commercial elevators, operator selection for road worthiness precluded that the sample represented all tractors on these farms.

A slower than average harvest during 1992 resulted in intermittent unloading at commercial grain elevators. Because of fewer grain transports unloading during a fixed period of time, usable data was received from five chapters that surveyed at six sites scattered in each of the four geographic quadrants of Iowa. Since participating sites were self-selected, data was representative of tractors and wagons transporting grain to these sites and did not represent the entire Iowa tractor and wagon population. Most equipment operators appreciated the check and safety reminder. One operator comment addressed a crucial issue for using these safety devices when she referred to the "difficulty of paying for wagon lighting with $1.75/bu corn."

A total of 130 checks were returned with usable data. Omitted data on some evaluations reduced the total tractors checked for ASAE standards to 105 and total wagons checked to 106 (Iowa code and hitch pin retainer) and 105 (ASAE standards).

Survey Results

Tractor status

Table 2 presents the percentage of tractors by age class complying with Iowa code safety standards. As measured by a probability greater than 0.5 of meeting compliance, tractors in

each age class had at least a single front white light and a SMV emblem. Tractors less than eight years of age had at least one rear red light and an amber flashing light. Only tractors within this age category met all Iowa code safety standards for travel between sunset and sunrise.

Table 2. Percentage of tractors by age class complying with Iowa code safety standards

	Tractor age (yrs)		
	0 - 7*	8 - 14†	15+*
Item description	--------- % ---------		
Forward white light, one	98‡	100‡	96‡
Rear red light, one	74‡	53	61
Rear amber flashing light, one	70‡	61	57
SMV emblem	87‡	79‡	70‡

* Number of tractors in age class = 46
† Number of tractors in age class = 38
‡ Probability of safety standard compliance > 0.5 at the $\alpha = 0.05$ level

There were no statistical differences among age groups for compliance with each safety item. Only half the items listed show a linear trend of increasing compliance with decreasing age. Because only tractors less than eight years of age had a probability greater than 0.5 of having rear lighting, data suggest maintenance or presence of rear red and amber flashing lights may be a problem. No statistical difference was measured for SMV compliance with tractor age.

Tractors in each age class measured against the stricter criteria of ASAE standards had two front white lights, two front amber flashing lights, and a ROPS (table 3). Tractors less than eight years of age met ASAE standards for a single rear red light and two rear amber flashing lights, but not for two rear red reflectors.

Within the zero to seven years age class tractor category, the lower percentage of compliance for two rear red reflectors than percentage of compliance for the single rear red light may have been due to a missing or inoperational (broken, mud-covered) taillight. Tractors in the middle-aged class had a slightly greater percentage of compliance for rear red reflectors than a rear red taillight. An opposite trend for tractors in the oldest age class may have indicated that only one red taillight was supplied as original equipment by the manufacturer.

A statistically significant difference existed among age classes for ROPS equipped tractors. Tractors less than 15 years old towing grain loads to the commercial elevators were more likely to have ROPS. No differences among age classes were measured for other safety items. Again, just half the items exhibited a trend toward increasing compliance with decreasing tractor age.

Only tractors less than eight years old had a probability greater than 0.5 of complying with standards for rear lighting and reflectors. This indicates that maintenance or lack of the presence of rear lighting and reflectors for tractors over seven years old was a problem.

Table 3. Percentage of tractors by age class complying with ASAE lighting and marking safety standard (S279.9) and ROPS standard (S383.1)

	Tractor age (yrs)		
	0 - 7*	8 - 14†	15+‡
Item description	--------- % ---------		
Front white lights, two, same height, laterally centered about tractor centerline	86§	95§	87§
Front amber flashing lights, two, same height, laterally centered about tractor centerline	76§	82§	65§
Rear red light, one, within 1.5 m (5 ft) of centerline	71§	45	54
Rear amber flashing lights, two, laterally centered about tractor centerline, within 400 mm (16 in) of lateral extremity	71§	50	48
Rear red reflectors, two, marking extreme left and right projections (tail light lens acceptable)	62	47	39
ROPS‖	100§	97§	67§

* Number of tractors in age class = 21
† Number of tractors in age class = 38
‡ Number of tractors in age class = 46
§ Probability of safety standard compliance > 0.5 at the $\alpha = 0.05$ level
‖ Safety standard compliance among age groups is different at the $\alpha = 0.01$ level

The slight differences for similar item categories between Iowa code and ASAE standards indicated the ability of tractors to meet standards stricter than those of state law. Combining all tractor age classes, only nine percent of tractors meeting the Iowa code for front lights did not meet the ASAE standard. Similarly, just six percent of tractors meeting the Iowa code for rear lighting did not meet the ASAE standard. A slight increase among new tractors meeting ASAE standards for rear amber flashing lights compared to those meeting Iowa code was related to sample size.

Greater differences among percentages complying with safety standards are noted when comparing front to rear lighting and marking. As measured by those items with a compliance probability greater than 0.5, tractors in the middle and older age groups met all front lighting and marking requirements but did not meet any rear lighting and marking requirement except the SMV emblem.

Wagon and hitch status

Among safety items checked, wagons had a compliance probability greater than 0.5 only for an SMV emblem and a retainer on the hitch pin (table 4). Compliance percentages for all other wagon items were lower than those of all tractor items. The data indicated a greater compliance for front and side amber reflectors than rear lighting and marking. The only rear marking for most wagons was an SMV emblem. Although not shown in table 4, for rear red lights on towed wagons, a statisticallly significant difference existed among wagons attached to tractors of different age classes. The percentage of wagons complying with standards was greater for wagons behind tractors over 14 years of age (Iowa = 43%, ASAE = 39%).

Differences between Iowa code and ASAE standard compliance percentages for similar items were five percent for the rear red light and six percent for the rear amber flashing light. Compliance with the stricter ASAE red taillight standard required only repositioning of the light from the right to left side of the wagon.

Comparing the two ASAE hitch standards, wagons were likely to have a retainer on the hitch pin but unlikely to have used an approved safety chain.

Application

With the exception of ROPS, no statistically significant differences of compliance with safety standards among tractor age classes were measured. For similar safety items, differences between compliance for Iowa code and ASAE standards were small. Greater differences occurred when comparing front to rear lighting and marking. Data (Emery, 1993) indicated that almost half of all Iowa motor vehicle accidents involving farm machinery occur during the October through December time period. Among Iowa personal injury and fatality accidents involving farm vehicles or tractors, rear-end collisions were the most frequent type reported (Emery, 1993; Lehtola and Marley, 1992). These data and reports suggest that rear lighting and marking are important considerations for safety at all times, day and night.

The probability of complying with front lighting standards for tractors at these sites was greater than 0.5. Inspecting rear lighting and marking of tractors, however, only the SMV emblem was found to have a probability of meeting compliance standards greater than 0.5. A possible explanation for this difference is the maintenance of front white lighting for field work and the availability of an SMV emblem at minimal cost. Rear red lighting may be viewed as more for the benefit of others (motorists) with little direct production value. Operators do exhibit a safety concern, however, by maintaining front amber lights that have no immediate impact on agricultural production. Upkeep of rear lighting and reflectors may be more difficult if their positions are exposed to mechanical damage during equipment positioning operations or if mud, manure, snow, or other debris covers or damages a lens. Equipment operators should be encouraged to maintain rear lighting and marking at least as well as they maintain front lighting.

Safety lighting and marking on wagons was generally neglected with the exception of the SMV emblem. Equipment operators put greater reliance on the SMV emblem for rear marking than any other device. Greater percentages of compliance for amber front and side wagon reflectors also suggest a problem with the maintenance or presence of rear reflectors and lighting. Wagon manufacturers should evaluate placement and operators should be encouraged to maintain and procure the necessary lighting and reflectors.

Several low cost options to improve lighting and marking are suggested by the data. Operators with a single red taillight right of the wagon centerline may improve visibility by maintaining the light within 5 ft left of the centerline. The addition of red and amber reflectors where suggested does not require any external power supply. At a minimum, operators should remove debris from lenses and reflectors as well as replace bulbs and damaged lens and reflectors. Because of the frequency of rear end collisions occurring throughout the day, operators should add rear lighting, if needed, beyond just maintaining existing safety items and adding reflectors.

The use of a retainer on the hitch pin is becoming an accepted practice with many operators, but the use of an approved safety chain is not. Equipment dealers should promote retrofitting of chains, lights, and markings where appropriate.

Operators may be choosing to use the safest tractors and wagons available for grain transport. Tractors in all age groups had a greater than 0.5 probability of having a ROPS. Rear wagon lighting was generally absent, but wagons behind older tractors did more frequently have red taillights. Professionals influencing these operators may be able to build upon some practices already being exhibited.

Conclusions

At the Iowa commercial grain elevator sites surveyed, the data support the following conclusions about tractors and wagons delivering grain:

- Tractors had a probability greater than 0.5 of meeting safety standards for: headlights, front amber flashing lights, SMV emblem and ROPS. Tractors less than eight years old met safety standards for rear amber flashing lights and rear taillight.
- A greater percentage of tractors less than 15 years old was equipped with ROPS than was the percentage of older tractors equipped with ROPS.Compliance of safety items did not significantly differ among tractor age groups except for ROPS.
- Wagons had a probability greater than 0.5 of meeting safety standards for an SMV emblem and retainer on the hitch pin. Other wagon safety items all had lower compliance than all tractor safety items.

Non-compliance with rear lighting and reflector standards suggests operator maintenance and frequent cleaning of lens debris.

Table 4. Percentage of wagons and tractor/wagon hitches complying with lighting, marking, and hitch safety standards of the Iowa code and ASAE (S276.3, S279.9, S318.10, and S338.2)

Item description	Percentage complying
Iowa code*	
Rear red light, one	31
Rear amber flashing light, one	25
SMV emblem	81†
ASAE standards‡	
Rear red light, one, less than 1.5 m (5 ft) left of centerline	26
Rear amber flashing lights, two, laterally centered about wagon centerline, within 400 mm (16 in) of lateral extremity	19
Front amber reflector, one, marking extreme left (if wagon extends 1.2 m (4 ft) left of hitch)	38
Side amber reflector(s), spaced at intervals not to exceed 5 m (16 ft) (if wagon(s) extends more than 10 m (33 ft) behind hitch point)	37
Rear red reflectors, two, marking extreme left and right projections	18
Hitch pin retainer pin used	66†
Hitch safety chain used with hook latch and ASAE tag with load specification	30

* Number of wagons = 106
† Probability of safety standard compliance > 0.5 at the $\alpha = 0.05$ level
‡ Number of wagons = 105, except hitch pin retainer pin number of wagons = 106

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